MECE336 Microprocessors I
INTRODUCTION

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ÇANKAYA ÜNİVERSİTESİ
MEKATRONİK MÜHENDİSLİĞİ BÖLÜMÜ

CONTENT

- Embedded Systems and Microcontrollers
- PIC 16F84A Architecture
- Assembly Programming Basics
- Input/output Usage
- Arithmetic Operations
- Timers and Interrupts, Sleep Mode and Watchdog Timer
- Programming Examples

Grading and Literature

- Grading
  - 13 Laboratories (25%)
  - 1 Midterm Exam (25%)
  - 1 Final Exam (35 %)
  - 1 Project (15 %)
- Literature
  - Wilmhurst, Tim: "Designing Embedded Systems with PIC Microcontrollers: Principles and Applications", Elsevier Ltd., 2010 (ISBN: 9-78-1-85617-750-4) (Main Textbook)
  - Mazidi, Muhammad Ali, McKinlay, Rolin D., Causay, Danny: "PIC Microcontrollers and Embedded Systems", Pearson International Education, 2008 (ISBN: 0-13-600902-6)

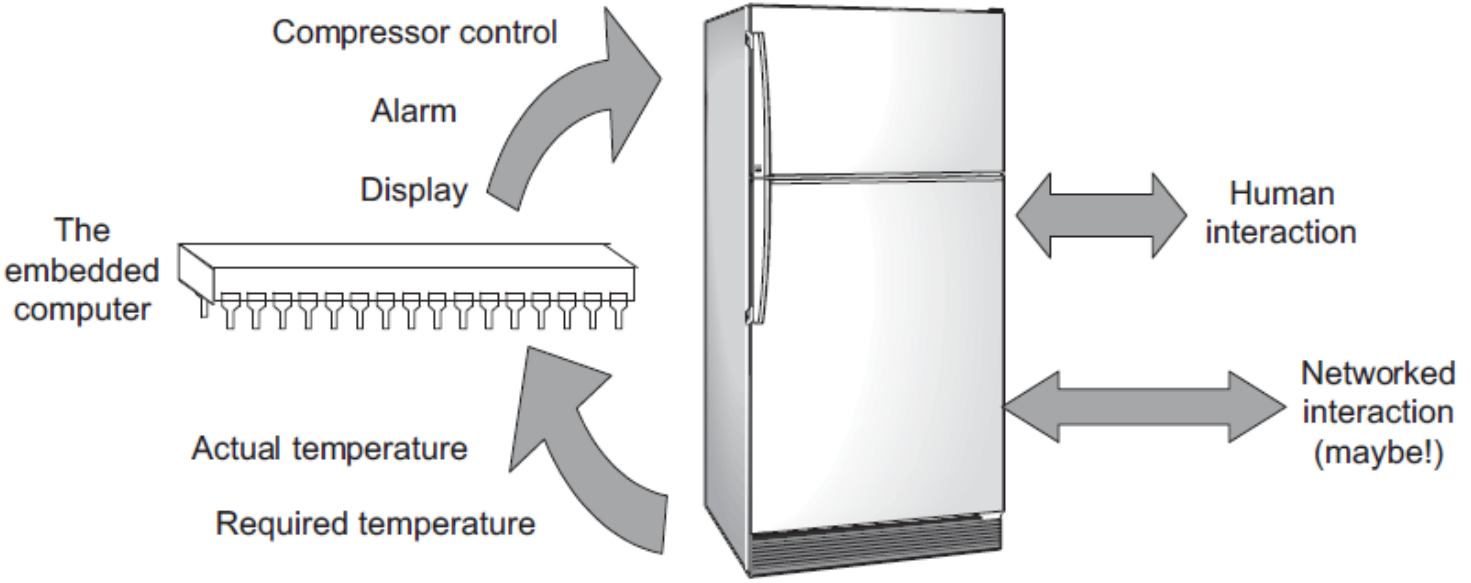
What is an embedded system?

- The basic idea of an embedded system is a simple one. If we take any engineering product that needs control, and if a computer is incorporated within that product to undertake the control, then we have an embedded system.
- An embedded system can be defined as:
  - A system whose principal function is not computational, but which is controlled by a computer embedded within it.

Home	Office and commerce	Motor car
Washing machine	Photocopier	Door mechanism
Fridge	Checkout machine	Climate control
Burglar alarm	Printer	Brakes
Microwave	Scanner	Engine control
Central heating controller		In car entertainment
Toys and games		

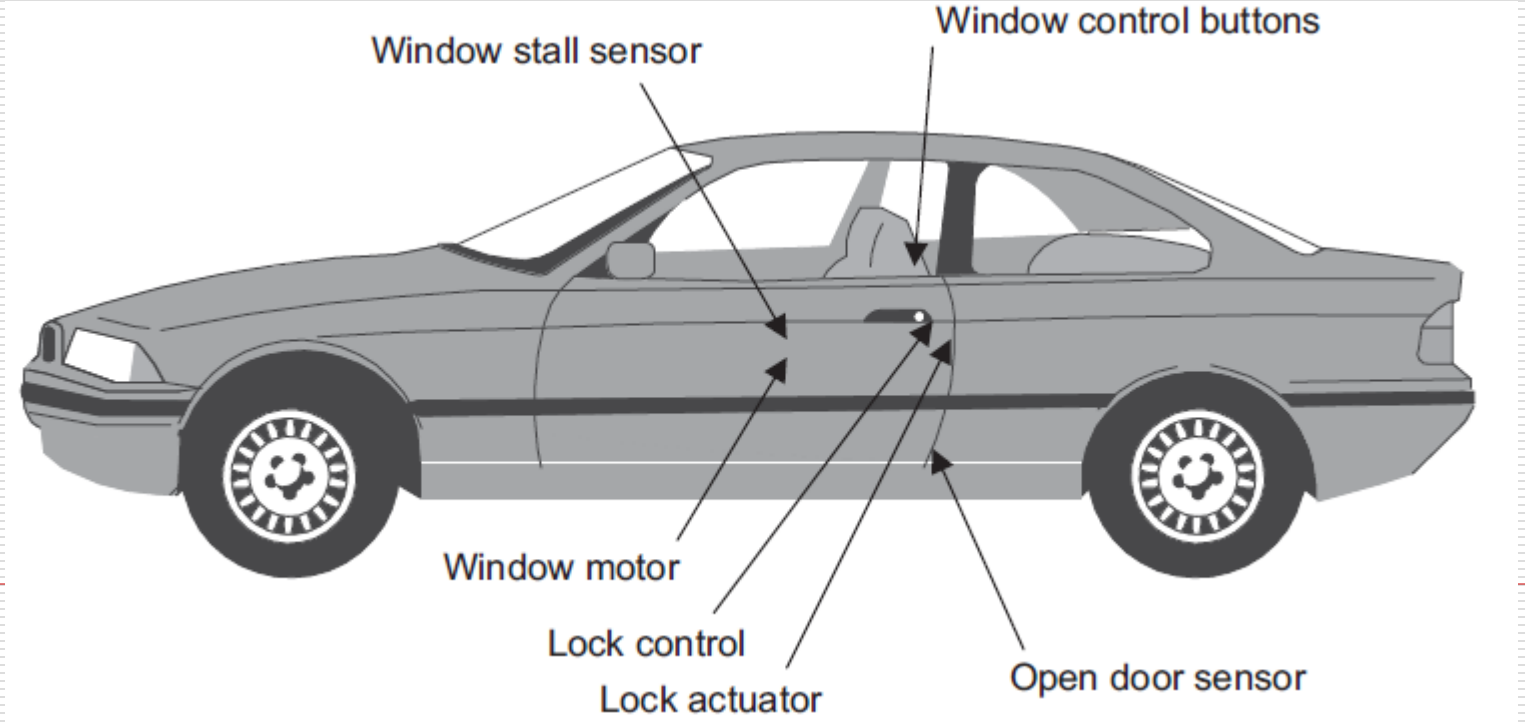
The domestic refrigerator

- maintains internal temperature by sensing temperature and comparing it with the temperature required, lowers the temperature by switching on a compressor.
- This process of control can be done by a conventional electronic circuit
- However embedded computer can help adding features like intelligent displays, more advanced control features, a better user control mechanism.



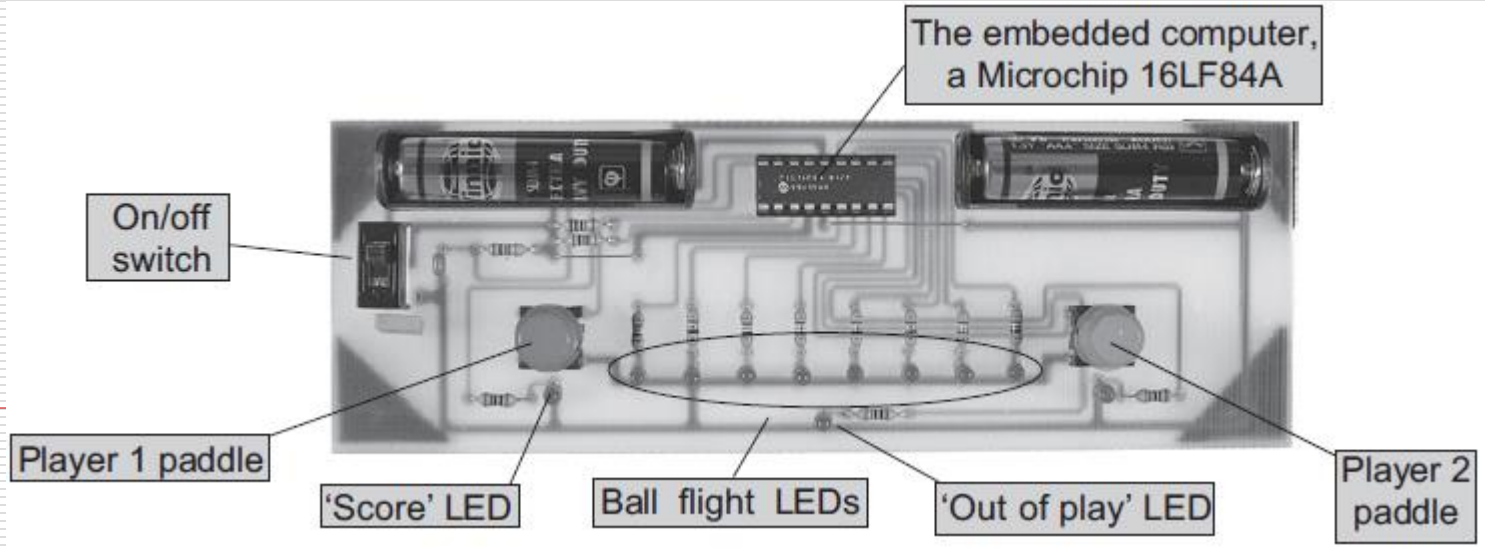
A car door mechanism

- A car door could be designed as a self-contained embedded system
- As car door's status and actuators under electronic control, they can be integrated with the rest of the car.
- Central locking can be introduced or an alarm sounded if the door is not locked when the driver tries to pull away.



The electronic ‘ping-pong’ game

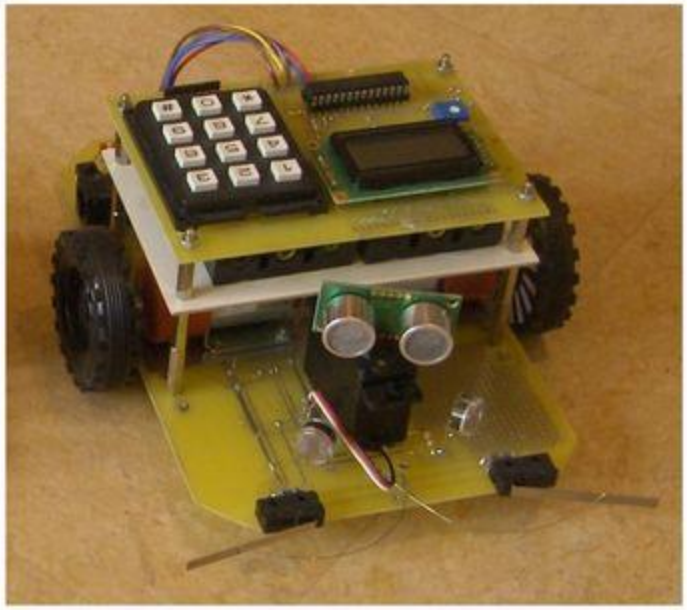
- It is a game for two players, who each have a push-button ‘paddle’. Either player can start the game by pressing his/her paddle.
- The ball, represented by the row of eight LEDs flies through the air to the opposing player, who must press his paddle only when the ball is at the end LED and at no other time.
- All the above action is controlled by a tiny embedded computer, a microcontroller, made by a company called Microchip, It takes the form of an 18-pin integrated circuit (IC).
- One of the memories contains a stored program, which it executes to run the game. It is able to read in as inputs the positions of the switches (the player paddles) and calculate the required LED positions. It then has the output capability to actually power the LEDs to which it is connected.

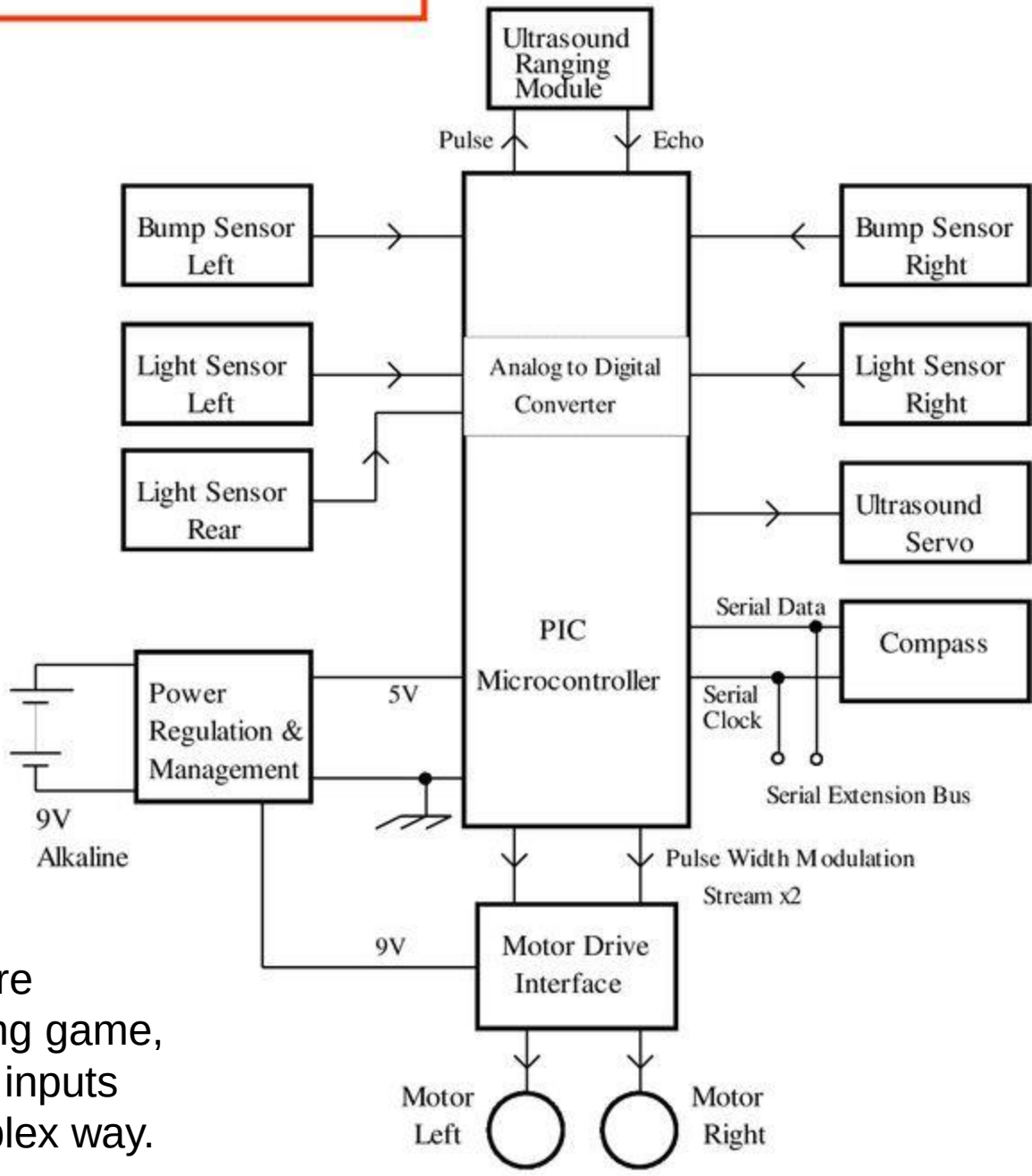


The Derbot Autonomous Guided Vehicle

- Two microswitch bump detectors sense if the Derbot hits an obstacle.
- An ultrasound detector, mounted on a servo actuator, is there with the aim of ensuring that the Derbot never has an unexpected collision!
- Two light sensors on either side of the servo are used for light tracking applications
- A further navigational option is a compass, so that direction can be determined from the earth's magnetic field.
- Locomotion is provided by two geared DC motors, while a sensor on each counts wheel revolutions to calculate actual distance moved.
- Steering is achieved by driving the wheels at different speeds.
- A piezo-electric sounder is included for the AGV to alert its human user.

Example 3: The Derbot Autonomous Guided Vehicle

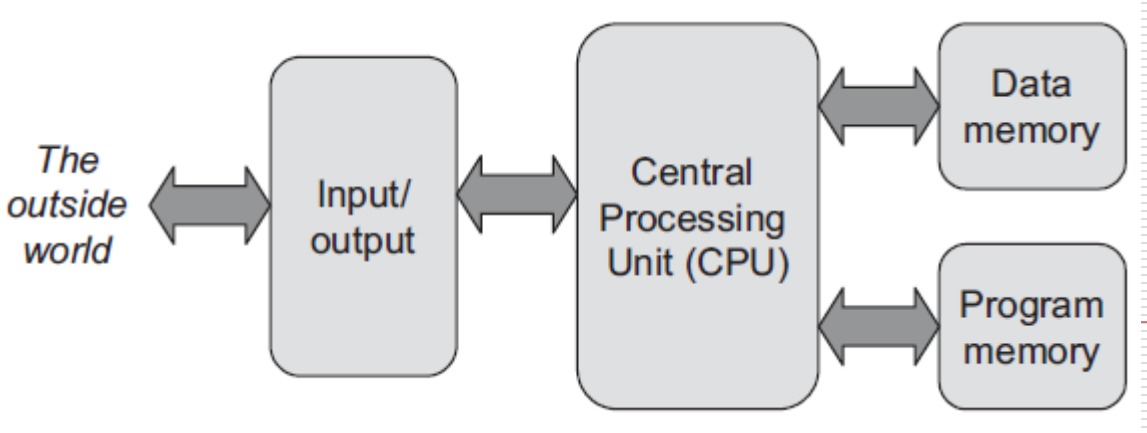




This microcontroller is seemingly more powerful than the one in the ping-pong game, as it needs to interface with far more inputs and drive its outputs in a more complex way.

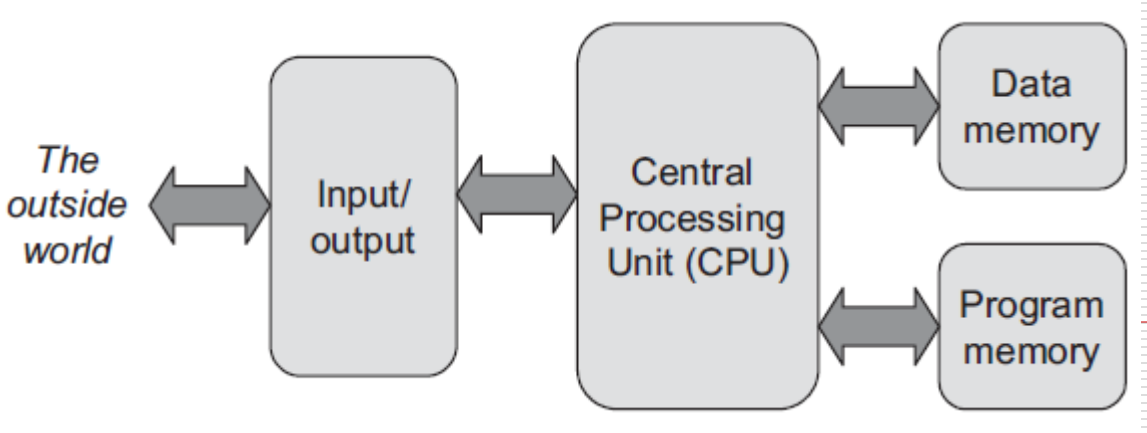
Embedded Systems: General Features

- CPU performs computations
- Program memory stores the instructions of the desired program
- Data memory stores application data values
- Input/output block for providing input data and reading output data
- Arrows represent data exchange



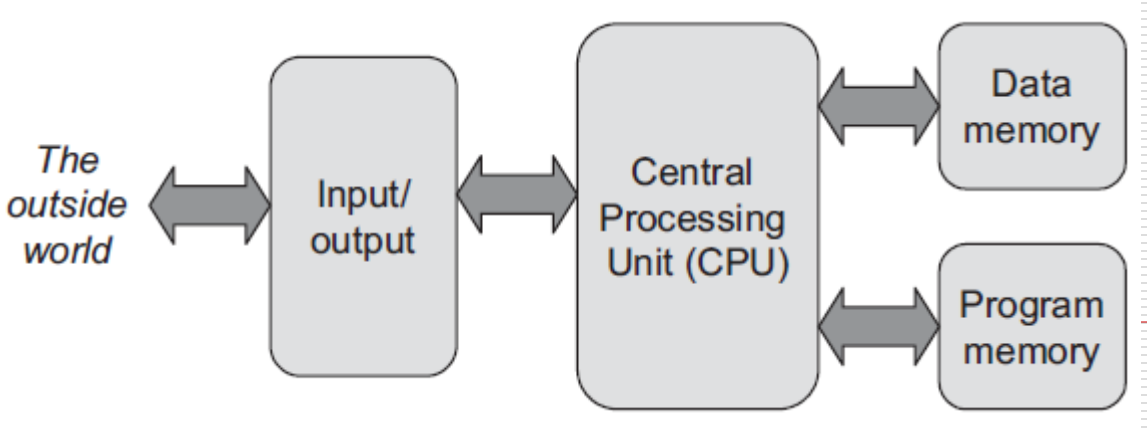
Central Processing Unit (CPU)

- Arithmetic or logical calculations are provided by the Central Processing Unit (CPU).
- It operates by working through a series of instructions, called a program, which is held in its memory.
- Any one of these instructions performs a very simple function.
- Many instructions cause mathematical and logical operations to occur.
- These take place in a part of the CPU called the ALU, the Arithmetic Logic Unit.



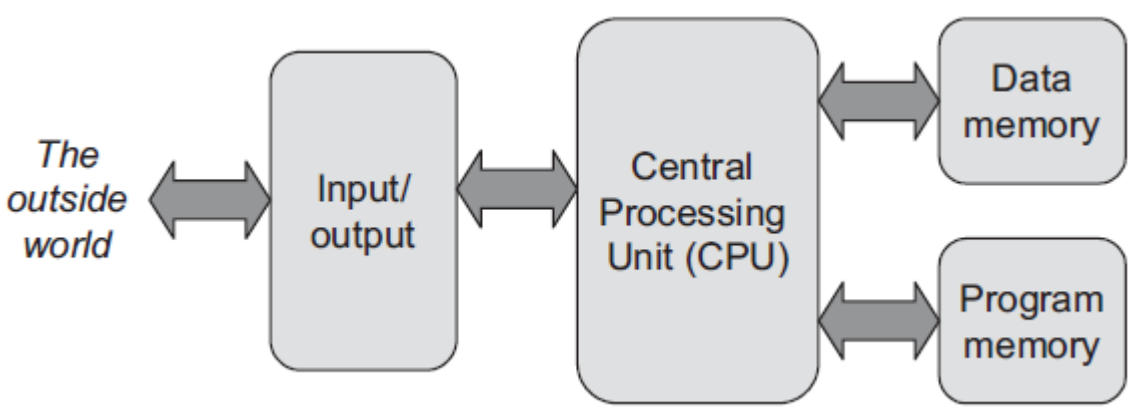
Input/Output

- To be of any use the computer must be able to communicate with the outside world, and it does this through its input/output.
- On a personal computer this implies human interaction, through the keyboard, VDU (Visual Display Unit) and printer.
- In an embedded system the communication is likely to be primarily with the physical world around it, through sensors and actuators.



Memory and Data Paths

- The computer revolution is taking place is due not only to the incredible processing power, but also to the equally incredible ability that we now have to store and access data.
- There are two main applications for memory in a computer, as shown in Figure.
- Program Memory
  - Holds program to execute
  - Needs to be permanent (also if there is no power)
  - Program is ready to run as soon as power is applied
- Data Memory
  - Holds temporary data values (results of a computation, . . .)
  - Need not be permanent (can be erased if there is no power)
- Data Paths
  - I/O , CPU
  - Data Memory , CPU
  - Program Memory , CPU



Instructions

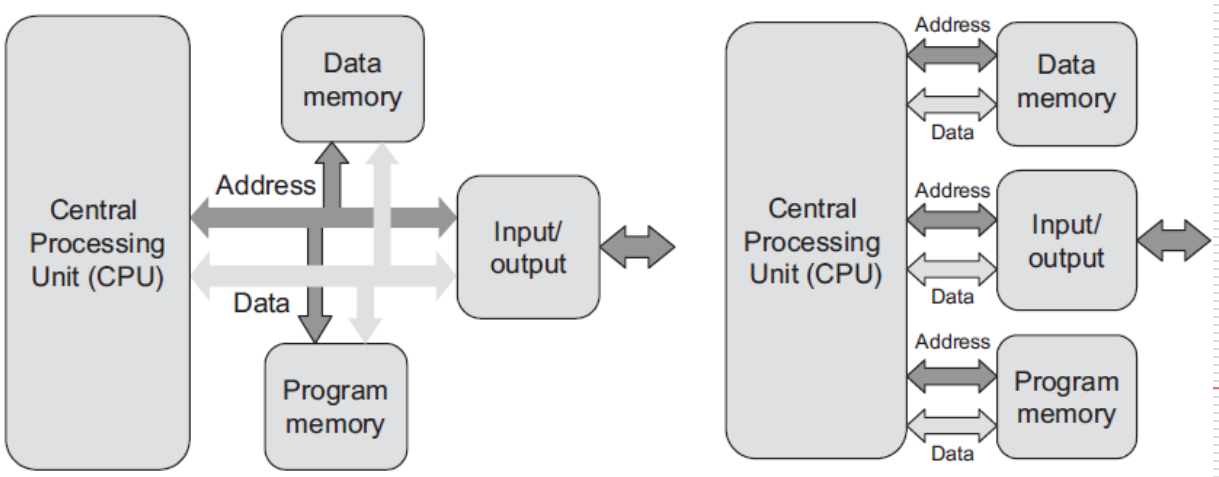
- Any CPU has a set of **instructions** that it recognises and responds to
- All **programs** are built up in one way or another from this **instruction set**.
- Some CPUs have vast instruction sets, with an instruction ready for every foreseeable operation.
- This leads to the **CISC, the Complex Instruction Set Computer**. A CISC have
  - **Complex instructions** defined by several bytes and take a long time to execute.
  - **Simple instructions** defined by several bytes and is executed quickly.
- Some CPUs have very simple and limited instruction set called **RISC approach – the Reduced Instruction Set Computer**.
  - Simple instruction set for fast operation
  - Each instruction is contained in a single binary word
  - Instruction includes code and address data

Memory types

- Volatile Memory.
  - loses its stored value when power is removed, but can be used as memory for temporary data storage.
  - uses simple semiconductor technology and is easier to write to from an electrical point of view.
  - been called RAM (Random Access Memory). A slightly more descriptive name is simply '**data memory**'.
- Non-volatile Memory.
  - This is memory that retains its stored value even when power is removed.
  - is harder to manufacture and more difficult to write to electrically, for example in terms of time or power taken, or complexity of the writing process.
  - is used for holding the computer program
  - called ROM (Read-Only Memory). A more descriptive name is '**program memory**'.

Organising memory

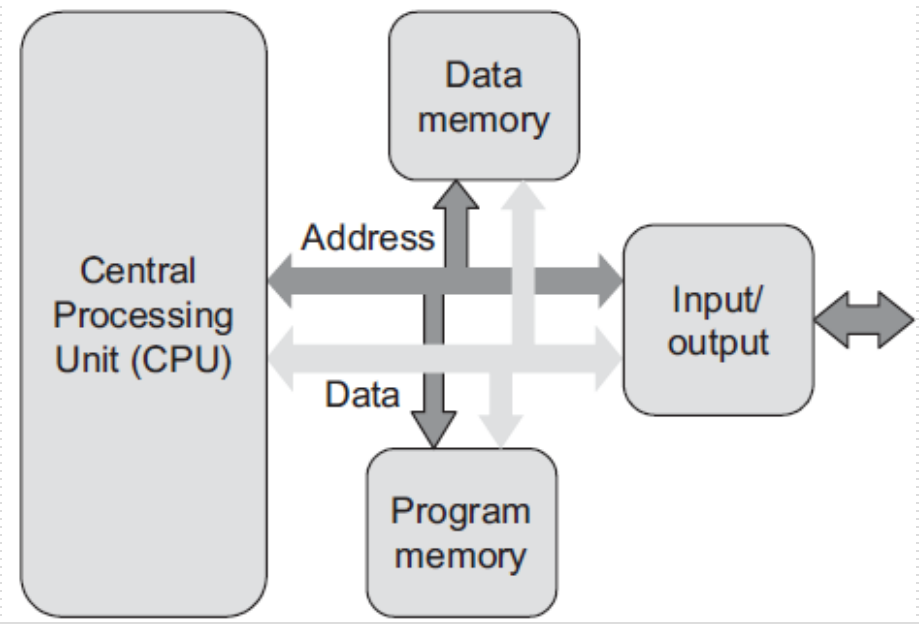
- To interact with memory, there must be two types of number moved around:
  - the address of the memory location required and
  - the actual data that belongs in the location.
- These are connected in two sets of interconnections, called the
  - address bus and
  - the data bus.
- We must ensure that the data bus and address bus (or a subset of it) reach every memory area.



(a) The Von Neumann way. (b) The Harvard way

Von Neumann Architecture

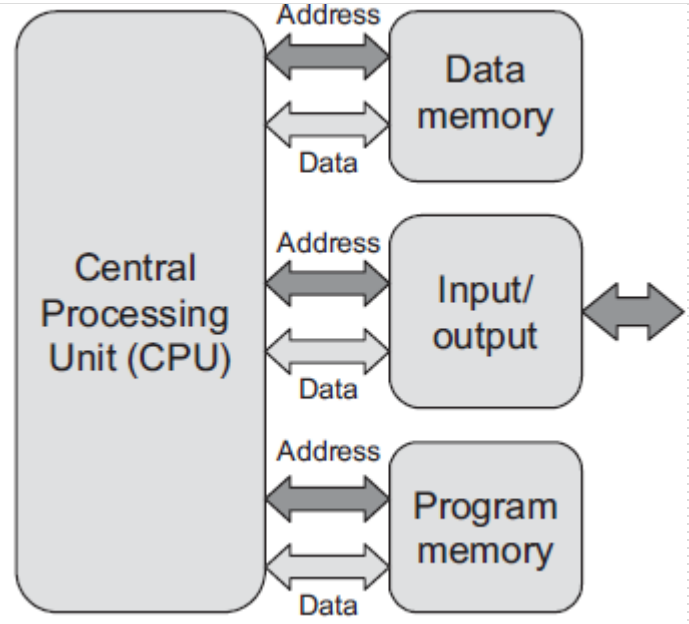
- The computer has just one address bus and one data bus, and the same address and data buses serve both program and data memories



- Advantage: Flexible division of memory in program and data memory
- Disadvantage: Shared) only one component can access at a time
- Disadvantage: Same bus for all memory sizes (small/large words)

Harvard Structure

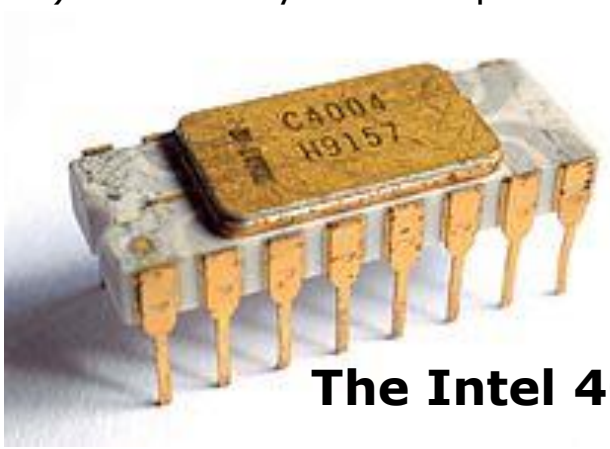
- Every memory area has own data bus
- Every memory area has own address bus
- Each bus only serves a single memory area



- Advantage: Flexibility in bus size depending on memory area
- Advantage: Simultaneous access of di erent memory areas
- Disadvantage: Program and data memory must be separate.
- Special case: when data is stored in program memory as a table, but is actually needed in the data domain.

Microprocessors and Microcontrollers

- The first commercially available microprocessor **The Intel 4004** is a 4-bit central processing unit (CPU) released by Intel Corporation in 1971.



The Intel 4004

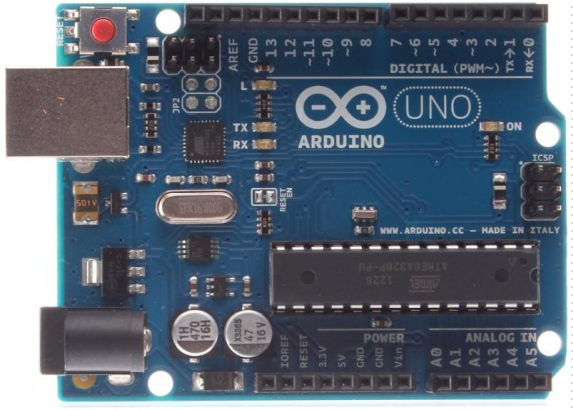
Modern Microprocessor

- These were amazing devices, which for the first time put a computer CPU onto a single IC.
- For the first time, significant processing power was available at rather low cost, in a comparatively small space.
- At first, all other functions, like memory and input/output interfacing, were outside the microprocessor, and a working system still had to be made of a good number of ICs.
- Gradually, the microprocessor became more self-contained, with the possibility, for example, of including different memory types on the same chip as the CPU.
- At the same time, the CPU was becoming more powerful and faster, and moved rapidly from 8-bit to 16- and 32-bit devices.
- The development of the microprocessor led very directly to applications like the personal computer.

Microcontrollers

- A special category of microprocessor emerged that was intended for control activities, not for crunching big numbers.
- Like a microprocessor, a microcontroller needs to be able to compute, although not necessarily with big numbers.
- It must have excellent input/output capability, for example so that it can interface directly with the ins and outs of the fridge or the car door.
- Embedded systems are both size- and cost-conscious, the microcontroller must be small, selfcontained and low cost.
- The microcontroller may need to put up with the harsh conditions of the industrial or motor car environment, and be able to operate in extremes of temperature.

Arduino is a the most popular development kit based on a microcontroller. Most of the Arduino models available are based on an 8-bit Atmel AVR microcontroller.



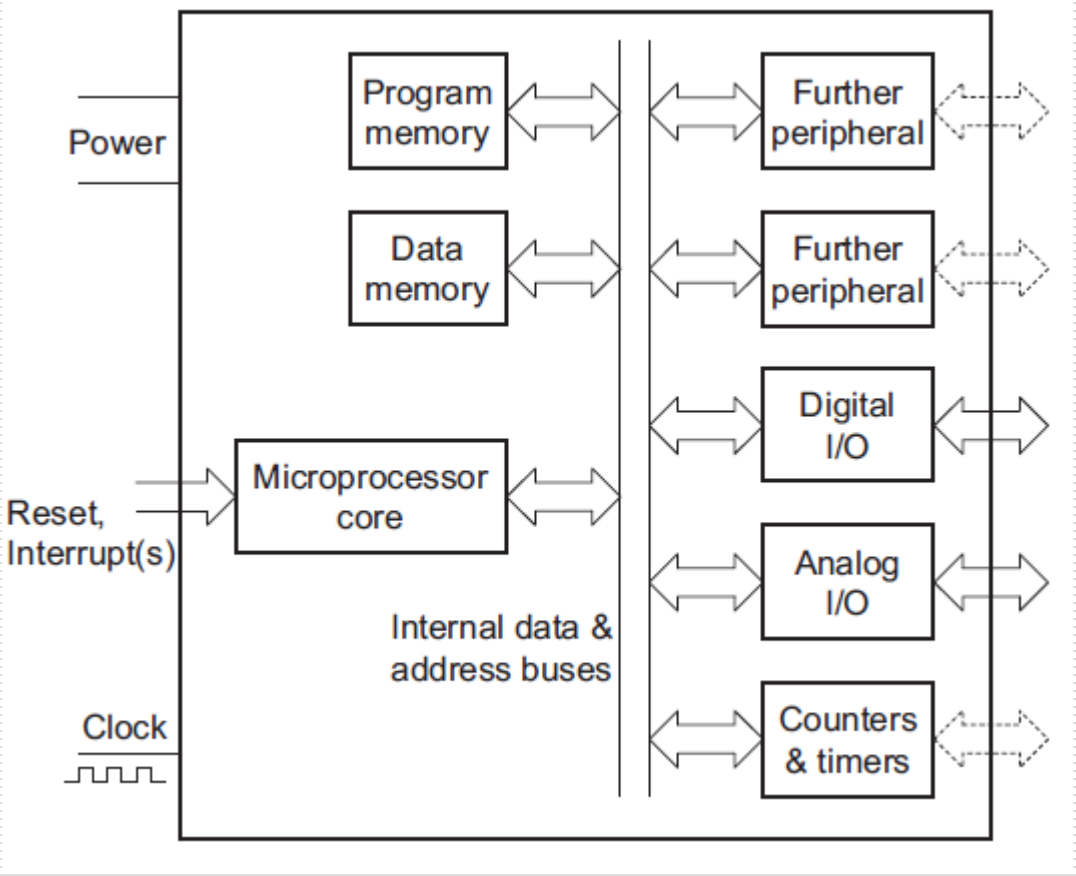
Key Differences Between Microcontrollers And Microprocessors:

	Microcontroller	**Microprocessor**
Design complexity	Low	High
Clock speed	Slow	Fast
Operating system	No	Yes
Processing speed	Low	High
Power consumption	Low	High
Memory	Small / Internal	Large / External
I/O pins	Yes	No
Number of bits	8-32 bits	32-64 bits
Cost	Low	High

https://predictabledesigns.com/introduction-to-microcontrollers/

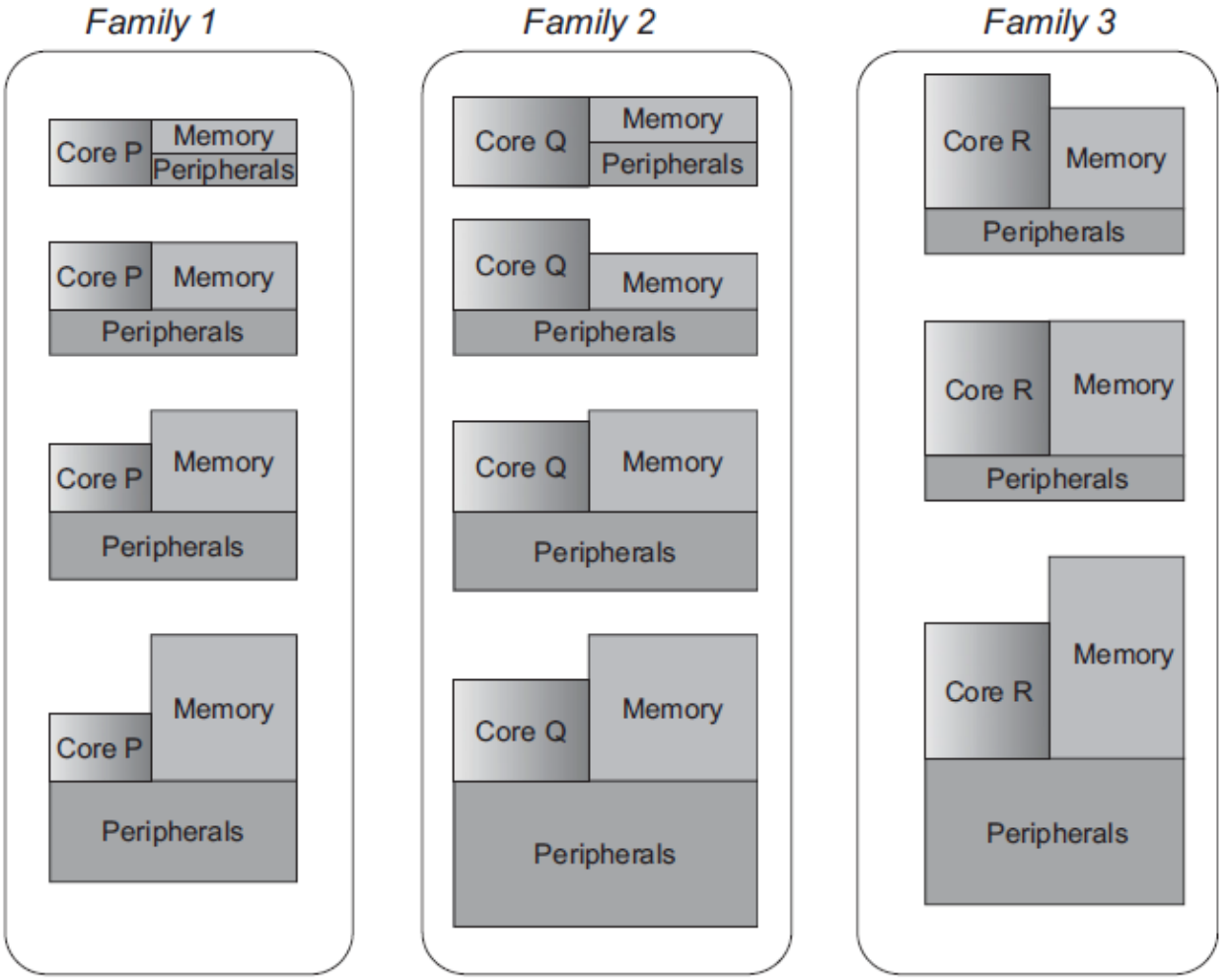
A Generic View Of A Microcontroller

- Components
  - Simple MP core
  - Data/program memory
  - Peripherals for
  - interfacing
  - Power, clock



Microcontroller Families

- A manufacturer builds a microcontroller 'family' around a fixed microprocessor core with different combinations of peripherals and different memory sizes.
- One core might be 8-bit with limited power, another 16-bit and another a sophisticated 32-bit machine.
- There can be more than 100 MPs in any one family, each one with slightly different capabilities and some targeted at very specific applications.

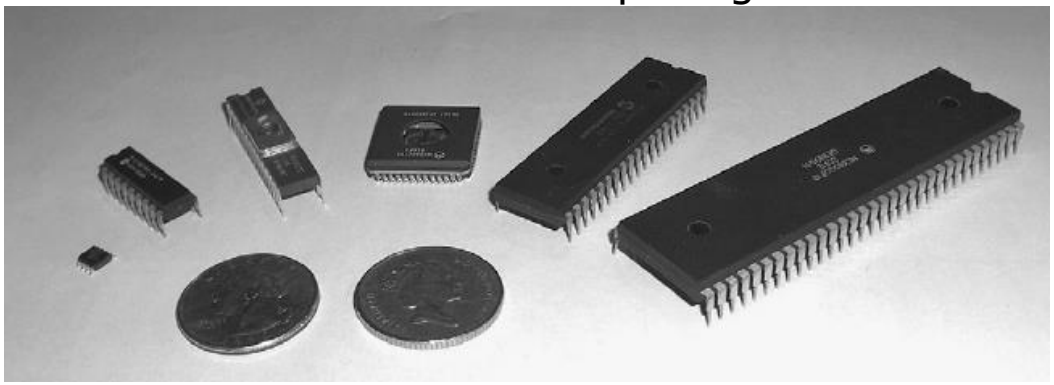


This lecture: PIC 16F84A microcontroller

Microcontroller Packaging And Appearance

- Rather than IC chip itself, in a conventional microcontroller, size is set by the number of interconnection pins provided on the IC and their spacing.
- Pins are used for
  - input/output
  - power
  - ground
  - clock signal
  - reset and
  - interrupt inputs
  - to transfer program

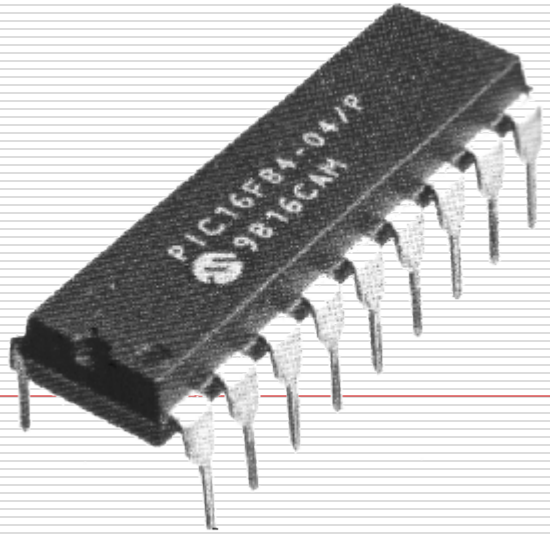
package is a dual-in-line package (DIP)



- 64-pin Motorola 68000 on the rigth is oldest one and the biggest due to the requirement of external memory connected by pins.
- Second from right is the comparatively recent 40-pin PIC 16F877 has on-chip program and data memory.
- 52-pin Motorola 68HC705 is in a square ceramic package, windowed to allow the on-chip EPROM (Erasable Programmable Read-Only Memory) to be erased. The pin spacing here is 0.05 inches
- To the left of this is a 28-pin PIC 16C72. Again, this has EPROM program memory and thus is also in a windowed ceramic DIP package
- On the far left is the tiny 8-pin surface-mounted PIC 12F508 and to the right of this is an 18-pin PIC 16F84A.

Microchip and the PIC microcontroller: ***Background***

- The Peripheral Interface Controller (PIC) was originally a design of the company General Instruments in the late 1970s.
- General Instruments produced the PIC 1650 and 1655 processors which was completely stand-alone with a simple CPU in a RISC structure having just 30 instructions.
- Throughout the 1990s the range of available PIC microcontrollers grew.
- Unlike many competitors, Microchip made their development tools simple and low-cost or free.
- Microchip stayed for a long while firmly entrenched in the 8-bit world.



PIC 8-bit microcontrollers today

- 8-bit PIC microcontrollers are lowcost, self-contained, pipelined, RISC, use the Harvard structure, have a single accumulator (the Working, or W, register), with a fixed reset vector.
- Microchip offer 8-bit microcontrollers with four different prefixes, 10-, 12-, 16-, and 18-, whic are called '12 Series', '16 Series', '18 Series', for example 10F200, or 18F242.
- Series can fall into more than one family. For example some 12 Series microcontrollers are baseline, others are mid-range.
- The 'F' insert indicates incorporation of Flash memory technology (still using CMOS as the core technology)

Family	Example devices	Instruction word size	Stack size (words)	Number of instructions	Interrupt vectors
Baseline	10F200, 12F508, 16F57	12 bit	2	33	None
Mid range	12F609, 16F84A, 16F631, 16F873A	14 bit	8	35	1
High Performance	18F242, 18F2420	16 bit	32	75, including hardware multiply	2 (prioritised)

- The **baseline PIC microcontroller family** represents the most direct descendant of the General Instruments ancestors.
- Baseline devices are ideal for really tiny applications, being packaged in small ICs (right down to only six pins, for example) that have analog-to-digital converters and EEPROM.
- There is strong interest in this end of the size range, and further additions to the family can be expected.
- **The mid-range family** has smaller size and **interrupts** allowing interfacing both with more sophisticated peripherals and with larger numbers of peripherals.
- **The high-performance family** has an instruction setof 75 and is designed to facilitate use of the **C programming** language

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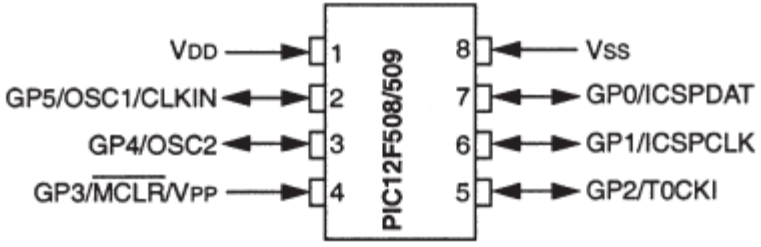
High Performance	18F242, 18F2420	16 bit	32	75, including hardware multiply	2 (prioritised)

An Introduction To PIC Microcontrollers Using The Baseline Series

- The features identified here will be recognisable in the more advanced PIC microcontrollers.

PIC 12F508/509 pin connection diagram

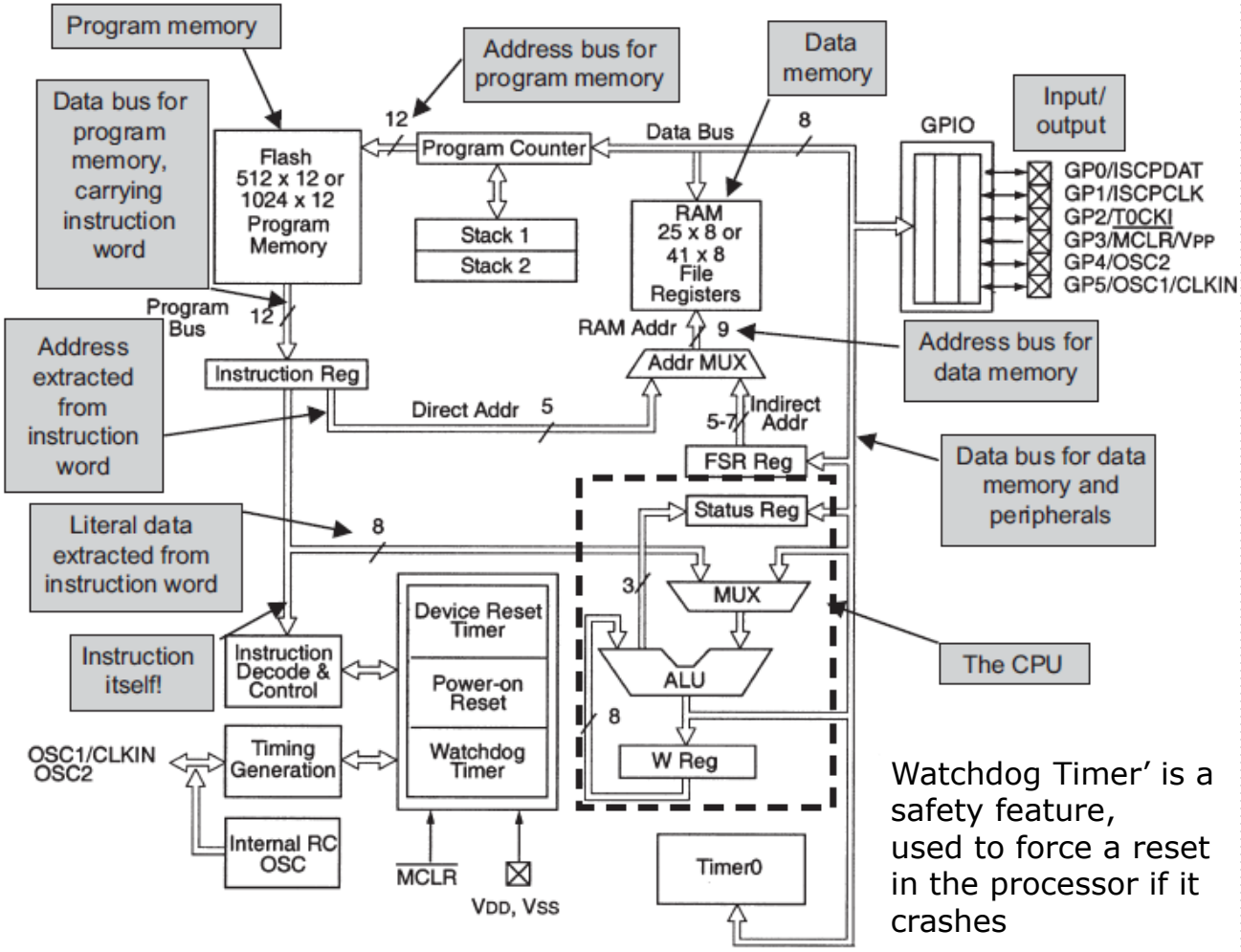


Key

V_{DD}:	Power supply	V_{SS}:	Ground
V_{PP}:	Programming voltage input	MCLR:	Master clear
OSC1, OSC2:	Oscillator pins	CLKIN:	External clock input
GP0 to GP5:	General Purpose input/output pins (bidirectional except GP3)		
CSPDAT:	In Circuit Serial Programming™ data pin.		
CSPCLK:	In Circuit Serial Programming™ clock pin.		

The architecture of the 12F508

- The CPU: ALU, the Working register (W Reg) and the Status register.
- Registers are RAM memory locations.
- Harvard structure using two address buses and two data buses.
- Using RISC, each instruction word carries instruction code itself, but also any address or data information needed.
- 12 bit Word is dived by instruction register into 5 bit for address, 8 bit for data
- Watchdog Timer' is a safety feature, used to force a reset in the processor if it crashes
- MCLR input can be used to place the CPU in a Reset condition



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